NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

May 14, 2021

MATERIALS LABORATORY FACTUAL REPORT Report No. 21-017

A. ACCIDENT INFORMATION

Place	:	Mesa, Arizona
Date	:	April 24, 2020
Vehicle	:	Bell UH-1H, N3276T
NTSB No.	:	WPR20LA130
Investigator	:	Samantha Link, AS-WPR, and Chihoon Shin, AS-40

B. COMPONENTS EXAMINED

Tail rotor assembly, 90° gearbox assembly, input quill assembly, and upper aft end of the vertical stabilizer.

C. DETAILS OF THE EXAMINATION

Overall views of the submitted components as received are shown in figure 1. The tail rotor blades and pitch change linkage had been disassembled, and the upper end of the vertical stabilizer had been cut to facilitate shipment to the NTSB Materials Laboratory. The tail rotor 90° gearbox assembly and tail rotor assembly had reportedly separated in flight. The attachment studs on the 90° gearbox case for attaching the gearbox assembly and input quill assembly to the upper aft end of the vertical stabilizer were fractured. The tail rotor blades were damaged at the leading edges near the blade tips and had multiple dents along the span of the blades. The pitch change control rod also was bent.

Views of the attachment surfaces for the tail rotor input quill assembly and 90° gearbox assembly and the corresponding mounting face on the upper aft end of the vertical stabilizer are shown in figure 2. The clock positions for the attachment studs and corresponding attachment holes are labeled on each piece, where the clock positions are as viewed looking forward and down on the vertical stabilizer. As assembled on the helicopter, 6 studs on the 90° gearbox case are inserted through corresponding holes in the shim plate (see figure 3), input quill sleeve flange (also shown labeled in figure 3), and the upper casting on the vertical stabilizer. The attachment is then secured with washers and nuts attached to the studs.

Another view of the input quill assembly and the corresponding mounting surface on the tail rotor 90° gearbox assembly is shown in figure 3. The input quill sleeve flange and shim plate were bent at the 2 o'clock position. Contact marks were observed around the sleeve corresponding to relative movement and off-axis contact between the sleeve and the 90° gearbox case opening. The input quill bearing inner race and cage were

separated from the outer race, and the rolling elements were missing. The bearing cage was bent, and several of the element separators were fractured. The nut adjacent to the input quill bearing was deformed and rubbed, and rubbing damage was present on the outer diameter of the input gear.

Curving contact marks and grooves were observed on the interior of the 90° gearbox as indicated in figures 3 and 4. The grooves and contact marks had sliding contact features consistent with off-axis contact with the rotating nut and input gear on the input quill assembly as the tail rotor 90° gearbox assembly separated from the input quill assembly.

The fractured 90° gearbox attachment studs and corresponding mounting surfaces on the 90° gearbox, input quill sleeve flange, and vertical stabilizer were partly covered with greasy deposits. The deposits were cleaned from the surfaces by gentle cleaning using a soft-bristle brush dipped in a solution of Alconox detergent and warm water. After cleaning, the surfaces were rinsed with water then ethanol followed by drying with pressurized air. Images in figures 4 through 11 were taken after all components had been cleaned. The 90° gearbox is shown in the cleaned condition also in figures 2 and 3.

Fracture surfaces for each of the 90° gearbox attachment studs are shown in figure 5. The studs were fractured mostly in the plane of the 90° gearbox case mounting surface. Steps in the fracture surface plane (ratchet marks) were observed emanating from the edges of the fracture origins in the areas indicated with unlabeled brackets, features consistent with cracks with multiple origins. The origin areas were located on opposite sides of the studs, consistent with crack growth under reverse bending. Curving crack arrest lines were observed on the stud fracture surfaces consistent with progressive crack growth, and dashed lines in figure 5 indicate the extent of progressive crack growth from each origin area. The surfaces associated with progressive crack growth were relatively rough, consistent with low-cycle fatigue or cyclic overstress crack growth under relatively high cyclic stresses.

The origin areas were approximately centered on each side of the stud on the clockwise and counterclockwise side, consistent with torque loading about the input quill opening axis in both the clockwise and counterclockwise loading directions. For studs at the 10, 12, and 2 o'clock positions, cracks that propagated in the clockwise direction (as viewed from above) extended much further than those that propagated in the counterclockwise direction. In the remaining three studs on the lower half of the gearbox case, the crack propagation in each direction was more equal.

The upper aft surface of the vertical stabilizer is shown in figure 6. The mating piece of the stud at the 8 o'clock position remained trapped in the corresponding attachment hole, and the nuts and washers remained attached to the stud as shown in figure 7. Brown sealant had been applied around the outer edge of the joint between the input quill sleeve and the vertical stabilizer, and the mounting face was outlined with fractured sealant material on the vertical stabilizer surface. Sealant on the outer side of the fracture was painted with black paint over bright white paint consistent with paint observed on the exterior surfaces of the vertical stabilizer (see figure 1). A different

colored white paint with a more beige-colored tint over a green-colored primer was observed under the layers of black and bright white paint. The beige-tinted white paint and green primer were observed as the outermost paint layer on the mounting surface for the input quill sleeve within the sealant outline shown in figure 6. Additionally, the beige-tinted white paint layer was the outermost paint layer on the interior surface of the vertical stabilizer shown in figure 7 and was observed on the washer seating faces for the 90° gearbox attachment hardware.

Multiple layers of primer, paint, and sealant were also observed on the input quill assembly as shown in figures 8 through 10. At the lower forward end of the input quill sleeve and castellated nut, a layer of brown sealant was covered by yellow primer and beige-tinted white paint. The mounting surface on the sleeve flange that had mated to the vertical stabilizer was also coated with yellow primer and beige-tinted white paint except for areas that appeared rubbed by contact with the mating surface and two well-defined circular areas around attachment holes at the 6 o'clock and 12 o'clock positions.

A closer view of the input quill sleeve between the 10 o'clock and 12 o'clock positions is shown in figure 9. Bright white paint and black overspray was observed around the outside of the flange as indicated. The mounting surface was covered with yellow primer and beige-tinted white paint. Near the 10 o'clock position, additional layers of green primer and beige-tinted white paint were observed on the painted flange surface consistent with paint transfer from the corresponding surface on the vertical stabilizer.

A cross-section of the paint and sealant layers at the edge of the quill sleeve mounting flange is shown in figure 10. Fractured sealant in figure 10 is from sealant around the joints between the input quill sleeve, shim plate, and 90° gearbox case. As shown in figure 10, the input quill sleeve flange at the joint was covered with a layer of brown sealant, followed by yellow primer, beige-tinted white paint, another layer of brown sealant, and then bright white paint.

A sample of paint and sealant material was cut from the joint between the output quill sleeve and the 90° gearbox housing using a scalpel, and a cross-section of the collected sample is shown in figure 11. The collected coating layers consisted of a brown sealant at the surface followed by yellow primer, gray paint, another layer of yellow primer, and finally beige-tinted white paint on the exterior surface.

According to maintenance records for the accident helicopter, the tail rotor 90° gearbox was painted and installed on the accident helicopter in November 2012 and had accumulated 228.1 hours time in service (TIS) since installation. The tail boom and elevators had been painted white and black in January 2019, 39.0 hours TIS before the accident.

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Senior Materials Engineer

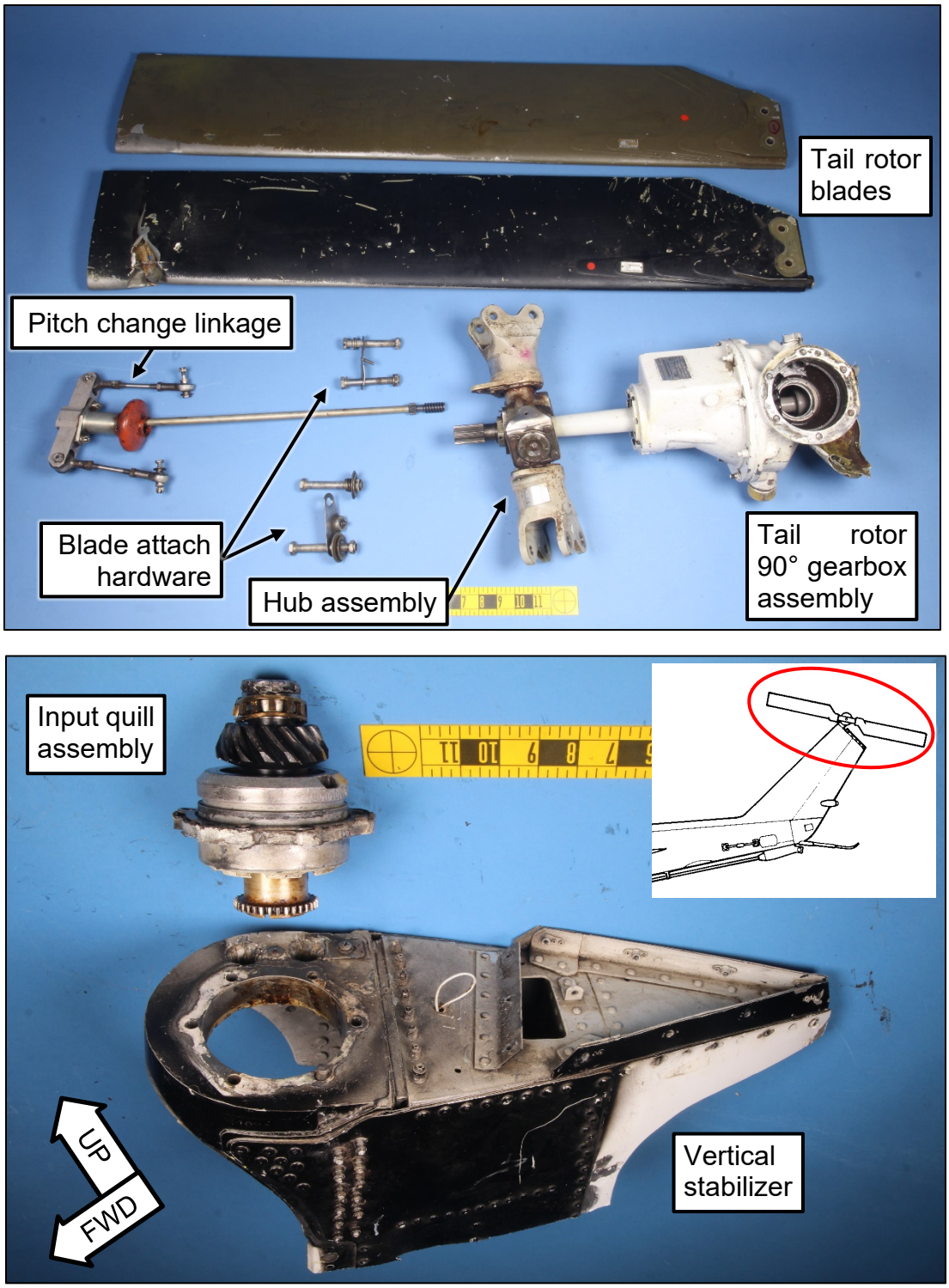

Figure 1. Overall views of the submitted components as received. The inset diagram shows the helicopter tail section with the location of the submitted components shown circled.

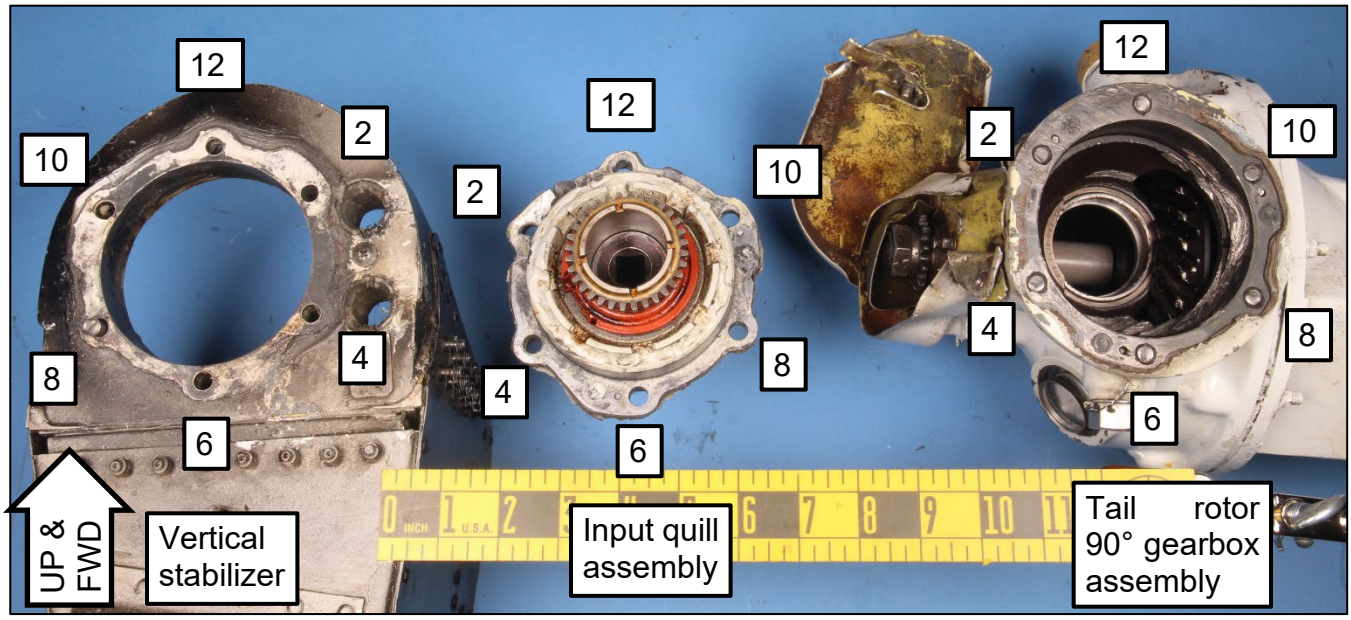

Figure 2. Upper aft side of the vertical stabilizer, mating surface of the input quill assembly, and mounting surface from the tail rotor 90° gearbox assembly. Mounting studs and corresponding attachment holes are numbered by clock position for reference.

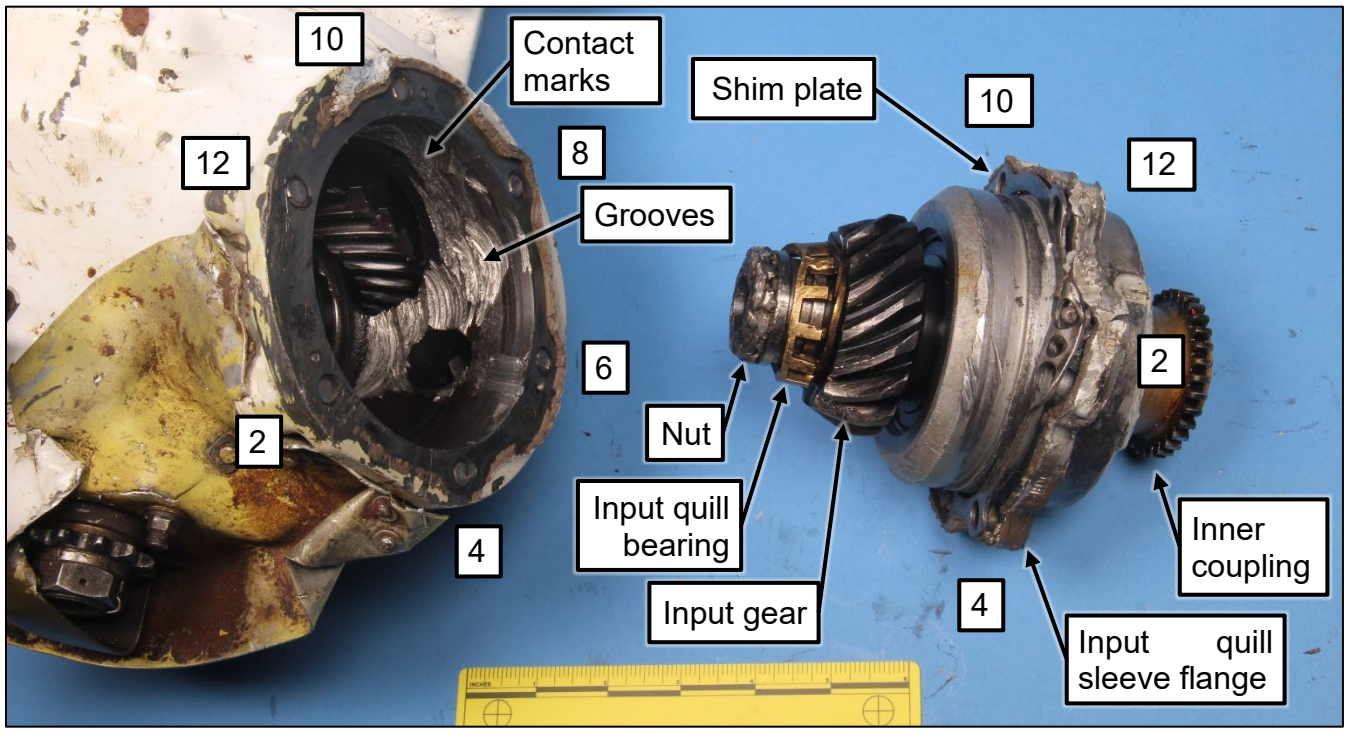

Figure 3. Input quill assembly and tail rotor 90° gearbox assemblies showing grooves on the interior surface of the gearbox housing and damage to the input quill bearing and adjacent nut.

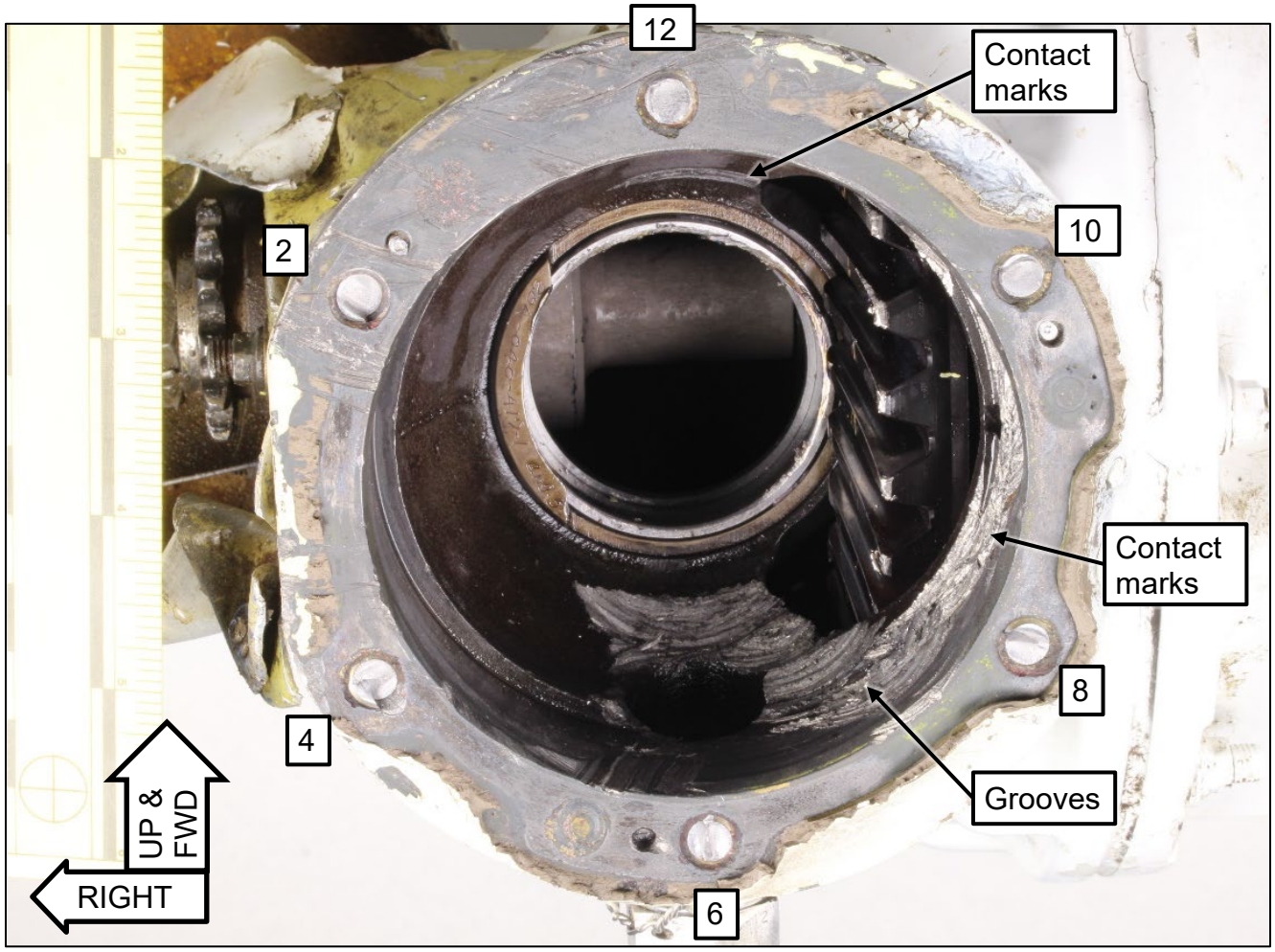

Figure 4. Mounting surface of the 90° gearbox assembly after cleaning. Fractured attachment studs are numbered by clock position as shown in figure 2.

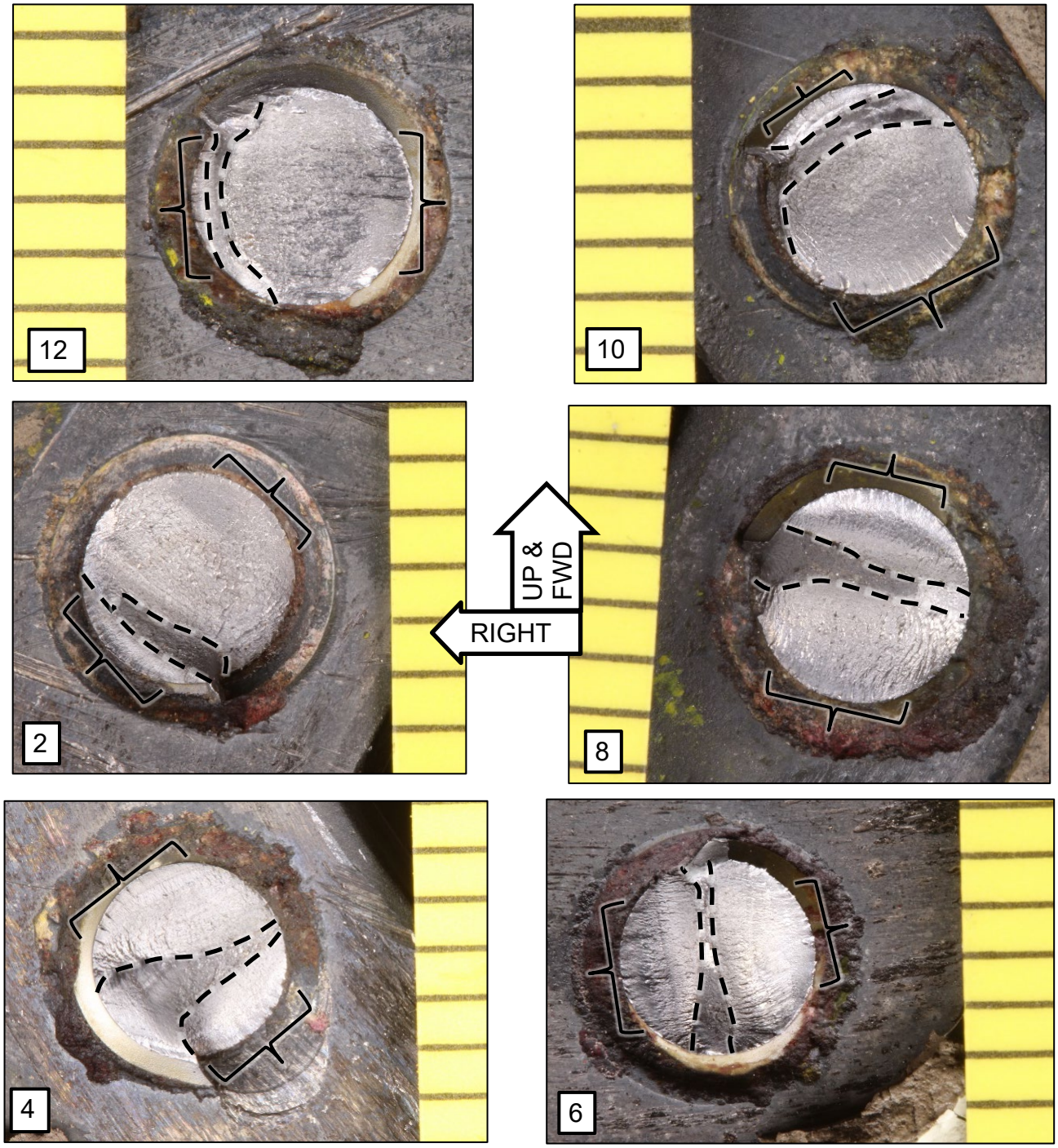

Figure 5. Close views of the 90° gearbox attachment stud fracture surfaces. Dashed lines indicate progressive crack growth boundaries, and brackets indicate crack origins.

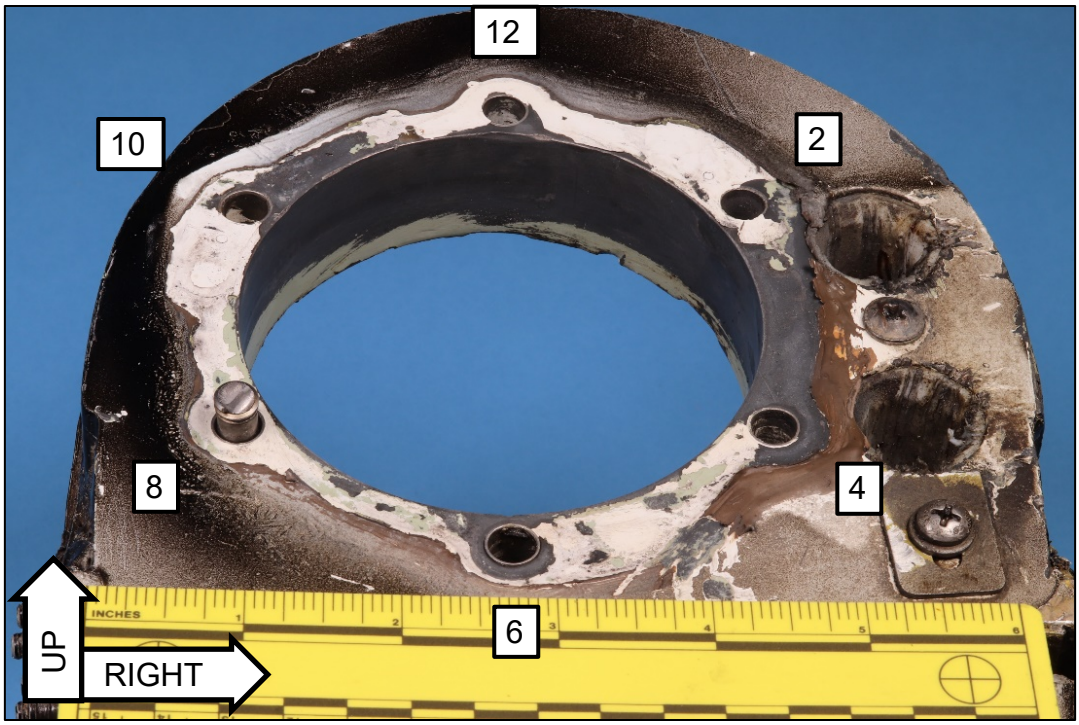

Figure 6. Upper aft surface of the vertical stabilizer after cleaning showing the mounting face for the 90° gearbox assembly.

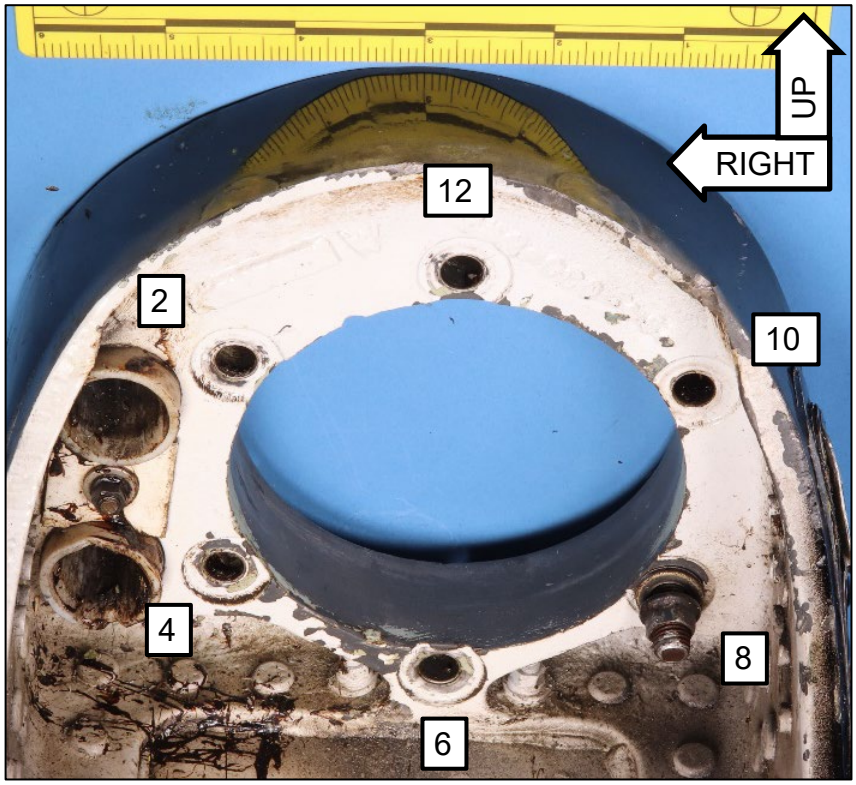

Figure 7. Lower forward surface of the support casting at the upper aft end of the vertical stabilizer after cleaning showing numbered mounting holes for the 90° gearbox assembly.

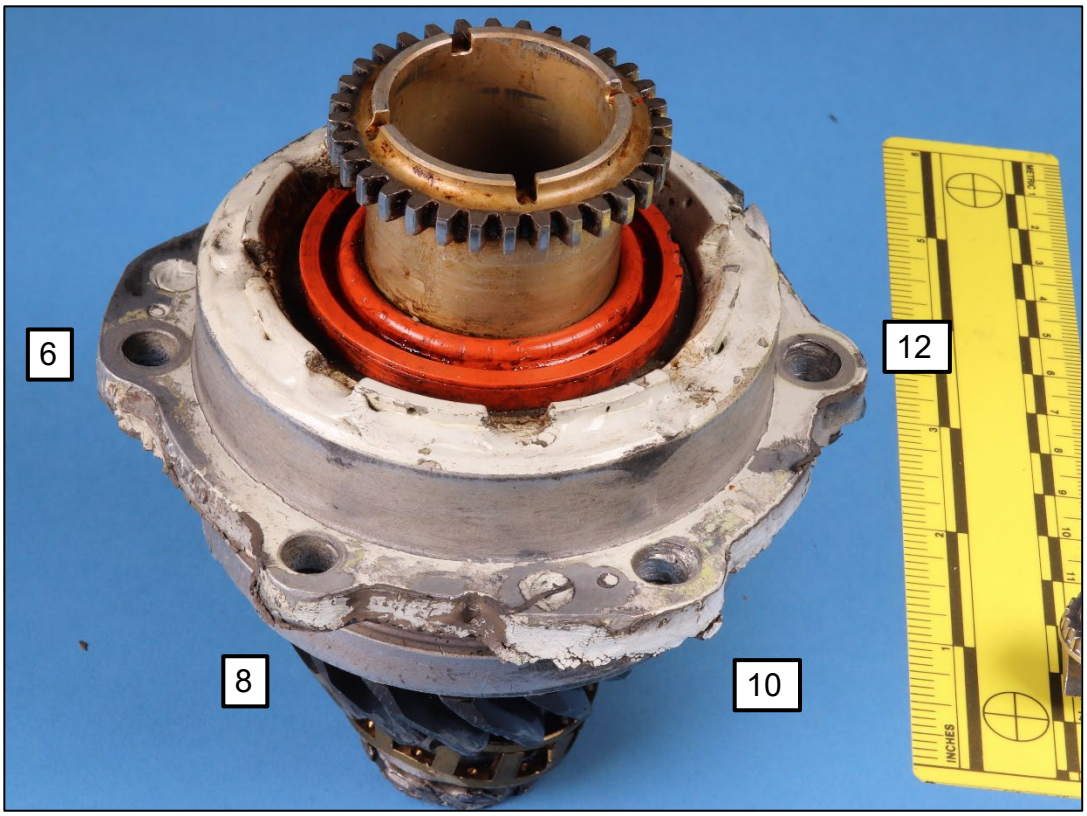

Figure 8. Lower forward side of the input quill assembly showing painted sleeve surfaces.

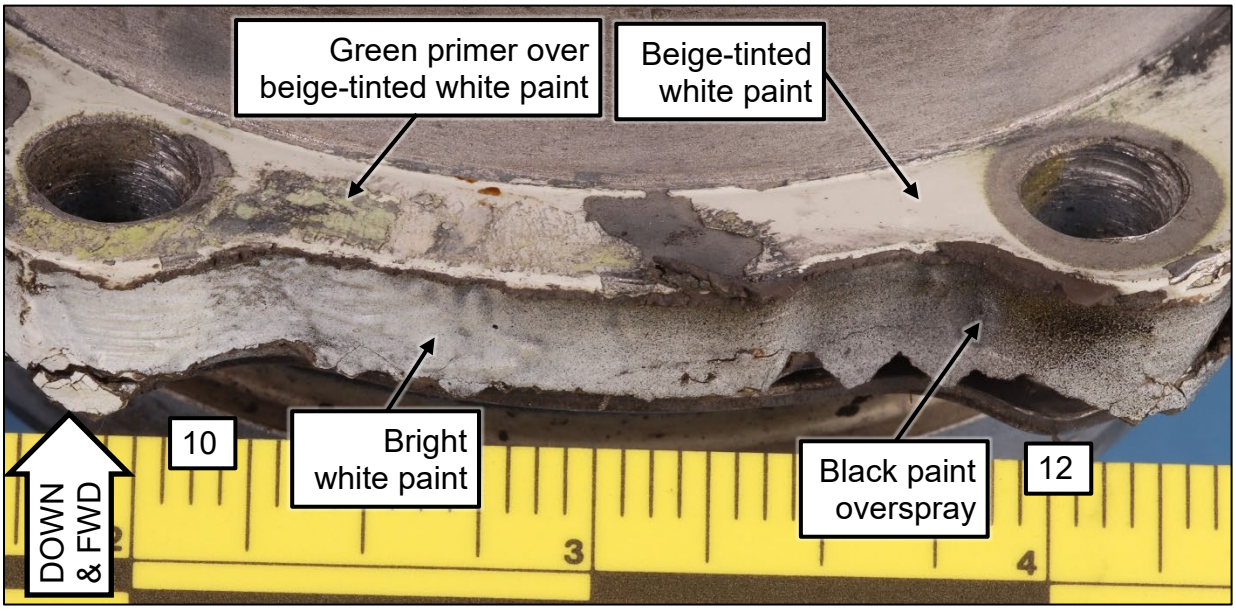

Figure 9. Input quill sleeve flange between the 10 o'clock and 12 o'clock mounting holes showing the mounting surface (vertical stabilizer side) and adjacent exterior surface.

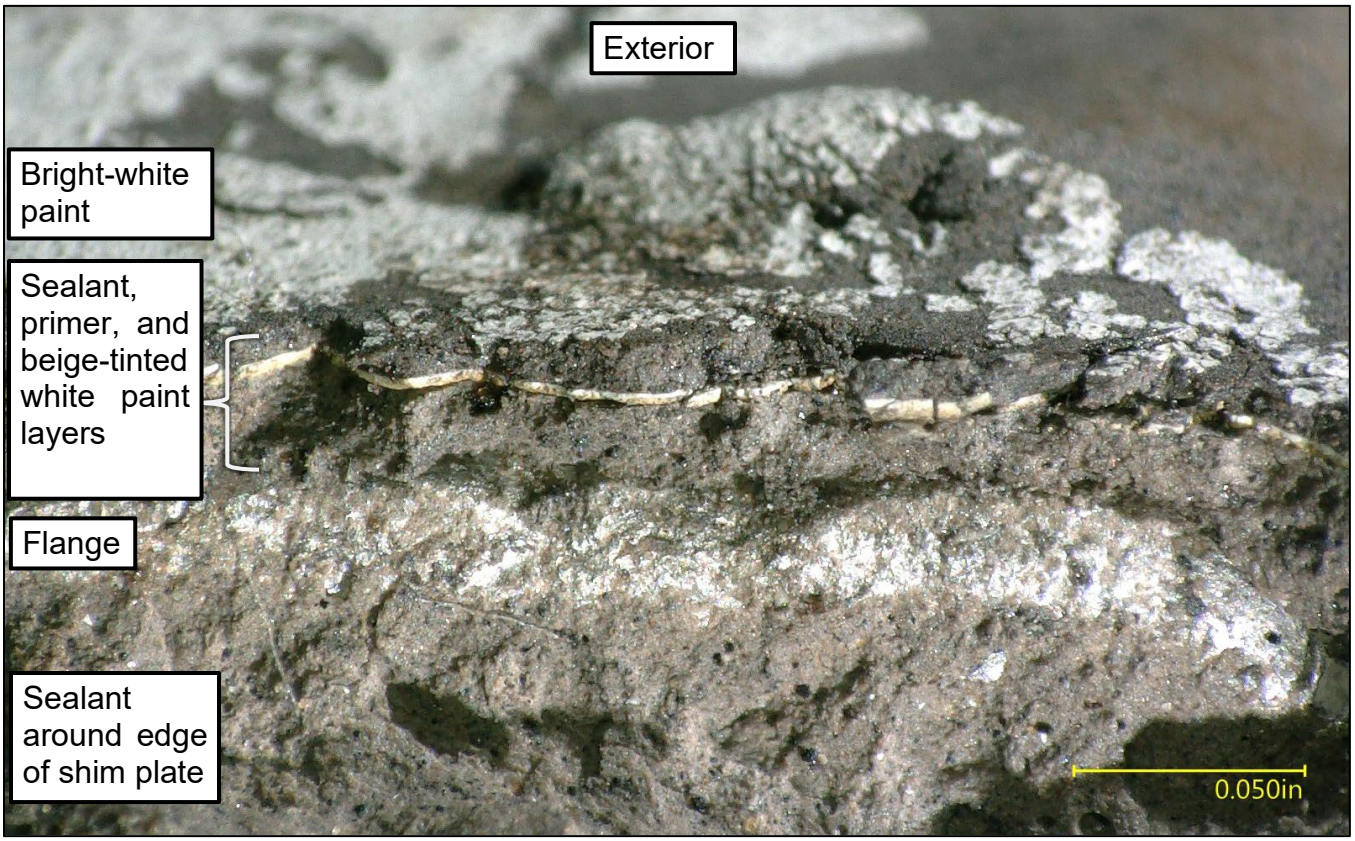

Figure 10. Edge of the input quill sleeve mounting flange showing sealant, primer, and paint layers on the side of the flange that mated to the tail rotor 90° gearbox.

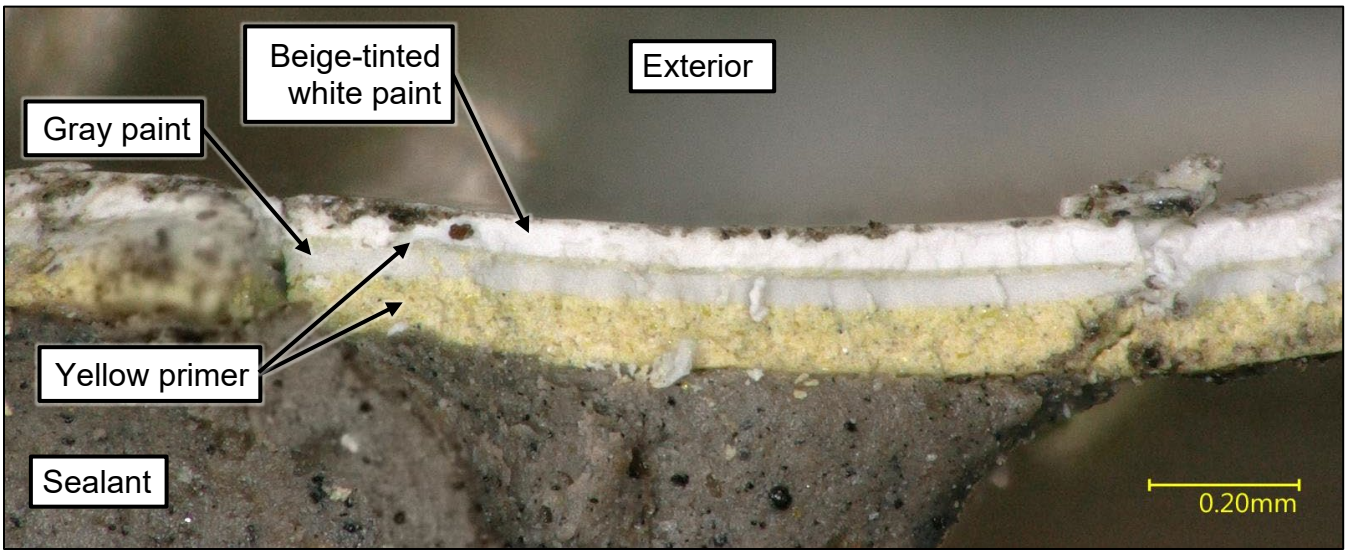

Figure 11. Sealant, primer, and paint layers on a sample cut from the joint between the output quill sleeve and the gearbox case on the 90° gearbox assembly.